A Sub-sector results

A.1 Background

This appendix contains estimates of multifactor productivity (MFP) in each of the eight mining sub-sectors covered in the study, along with estimates of the extent to which resource depletion and capital investment effects contribute to MFP changes over time.

The eight sub-sectors covered in the study and their shares of total mining industry value added in 2006-07 are shown in table A.1.

Table A.1 **Shares of total mining industry value added in 2006-07**

	$million	*Per cent*
1. Coal mining	16 364	22.8
2. Oil and gas extraction	22 420	31.2
3. Iron ore mining	11 208	15.6
4. Copper ore mining	3 699	5.2
5. Gold ore mining	2 629	3.7
6. Mineral sand mining	373	0.5
7. Silver-lead-zinc ore mining	4 339	6.0
8. Metal ore mining nec [a]	5 141	7.2
The industries not covered in this study are:		
Other mining	2034	2.8
Services to mining	3563	5.0
Total	71 770	100.0

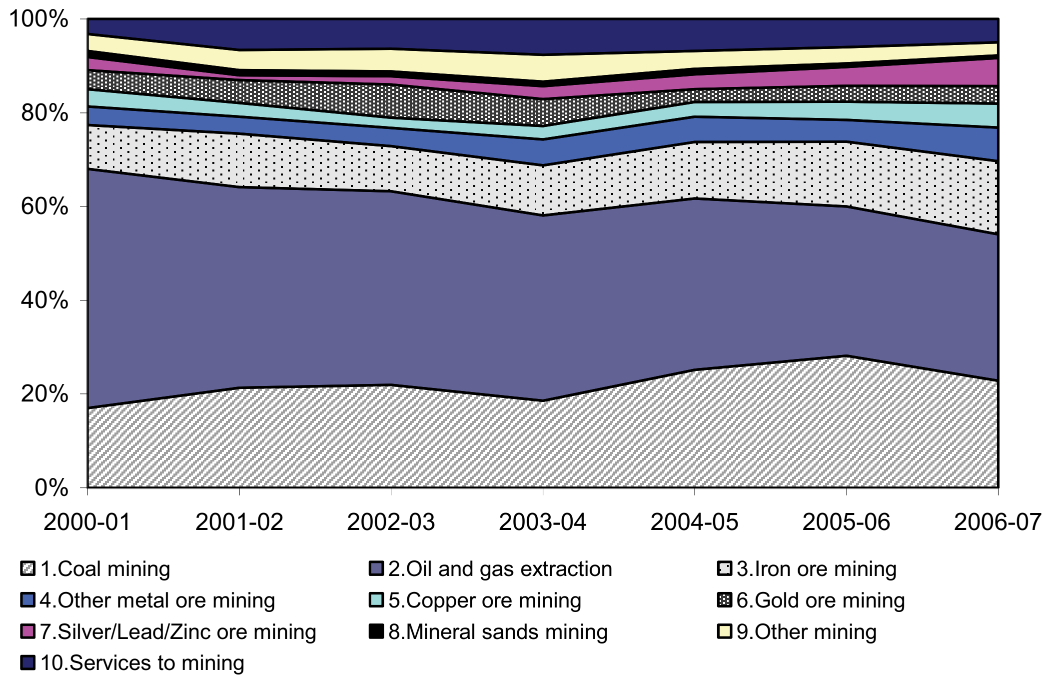
[a] Bauxite mining and nickel ore mining results are included in 'Metal ore mining nec'.

Source: ABS (*Mining Operations, Australia 2006-07*, Cat. no. 8415.0).

Changes in production and relative prices between 2000-01 and 2006-07 have led to changes in sub-sector shares of total mining output (figure A.1). Despite record prices in recent years, lower production of crude oil has caused a significant decline in the relative importance of the oil and gas sector. In contrast, increases in production and record prices for iron ore have resulted in a major new investment phase in iron ore mining, and an increase in the share of total mining output accounted for by this sub-sector.

The rest of this appendix outlines MFP changes on an industry by industry basis, with particular reference to developments in MFP growth since 2000-01.

Figure A.1 **Changes in industry shares of total output, 2000-01 to 2006-07[a]**



[a] Shares of industry value added in current price terms.

Data source: ABS (*Mining Operations, Australia 2006-07*, Cat. no. 8415.0)

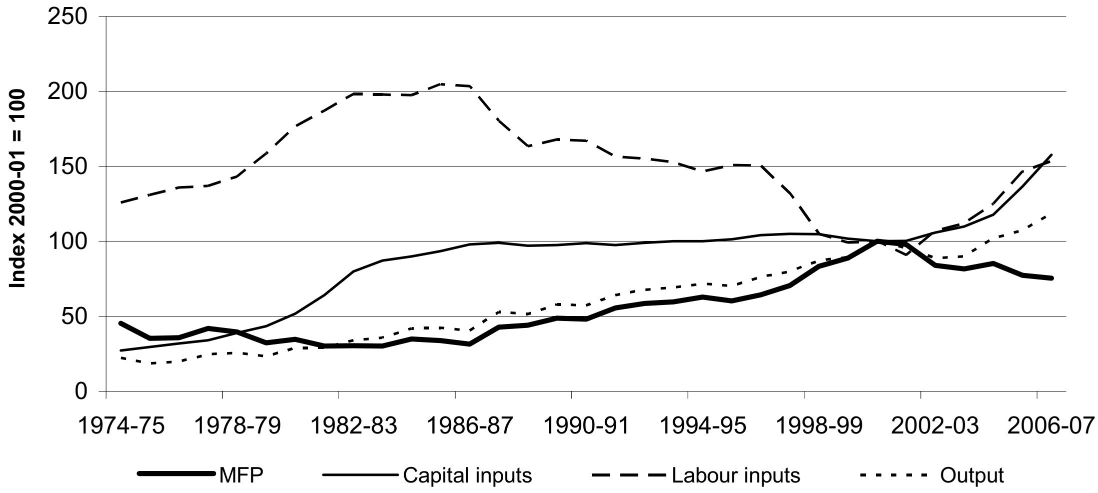
A.2 Coal mining

Coal mining has been a prominent feature of the mining landscape in Australia for over two centuries. Coal was first noted in Australia throughout the 1790s, and the first mineral exports from Australia were shipments of black coal sent to India in 1799 (Mudd 2007).

Until recent times the majority of Australian coal production served as an input to domestic industries, both as a source of fuel and as an input to steel making. From the mid-1960s, however, coal exports began to increase, and by the mid-1970s the quantity of coal exported from Australia exceeded the quantity sold domestically for the first time. Since then exports have continued to grow in volume and value terms relative to domestic sales, and now represent around three quarters of total production. The black coal industry accounted for 22.8 per cent of mining value added in 2006-07.

Measured MFP within the industry has declined in recent years following a steady improvement in productivity through the 1980s (figure A.2). The decline in recent years is a result of the substantial increase in inputs within the industry, with a comparatively modest increase in output. Coal production was particularly poor in 2002-03 as low prices encouraged some miners to scale-back production, and in 2005-06 as poor weather, difficulties with maintenance, and the closure of some depleted mines acted to constrain production growth.

Figure A.2 **Coal mining: Inputs, outputs and MFP**

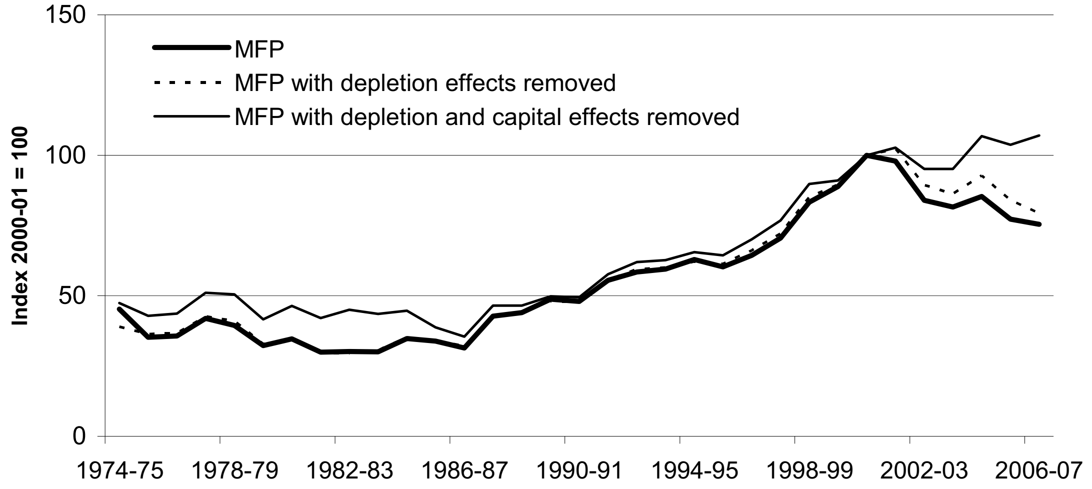


Data source: Authors estimates.

A decline in the saleable to raw coal ratio is estimated to have made a small contribution to the decline in MFP between 2000-01 and 2006-07 (figure A.3). It is also possible that an increase in overburden production in coal mining during the period contributed to the decline in MFP (figure A.4). However, further work needs to be done in order to quantify the effect on production costs of changes in the coal to overburden ratio.

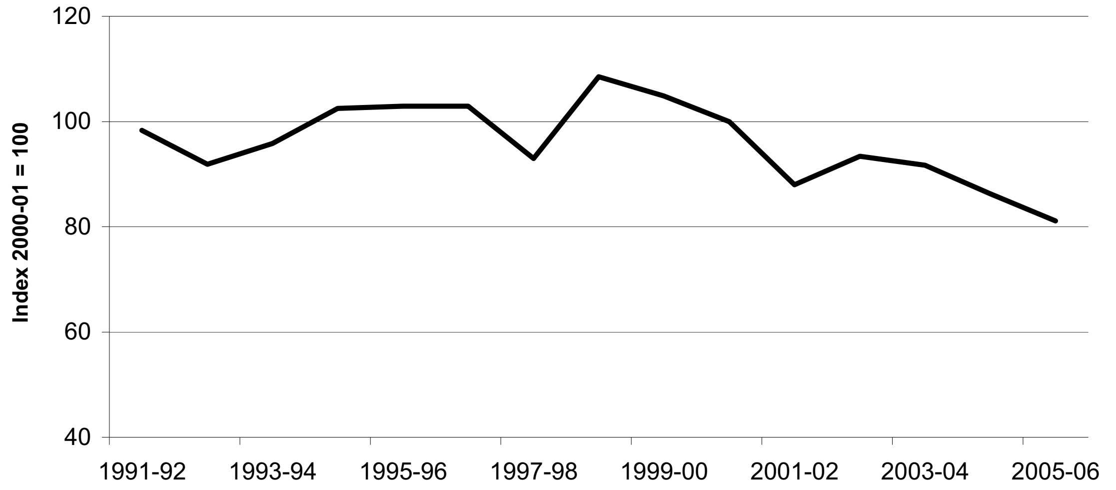
The effect of production lags has been significant in coal mining, with an investment surge from 2004-05, the scale of which is sufficient by itself to counter all of the productivity decline from 2000-01 onwards. As noted in chapter 4, the substantial lead time involved in most new mining developments means that a surge in new investment can lead to a temporary decline in MFP as inputs increase without an accompanying increase in output. Once the new coal mines and mine expansions currently under construction reach full production, there is likely to be an associated improvement in MFP.

Figure A.3 **Coal mining MFP: Impact of resource depletion and capital effects**



Data source: Authors' estimates.

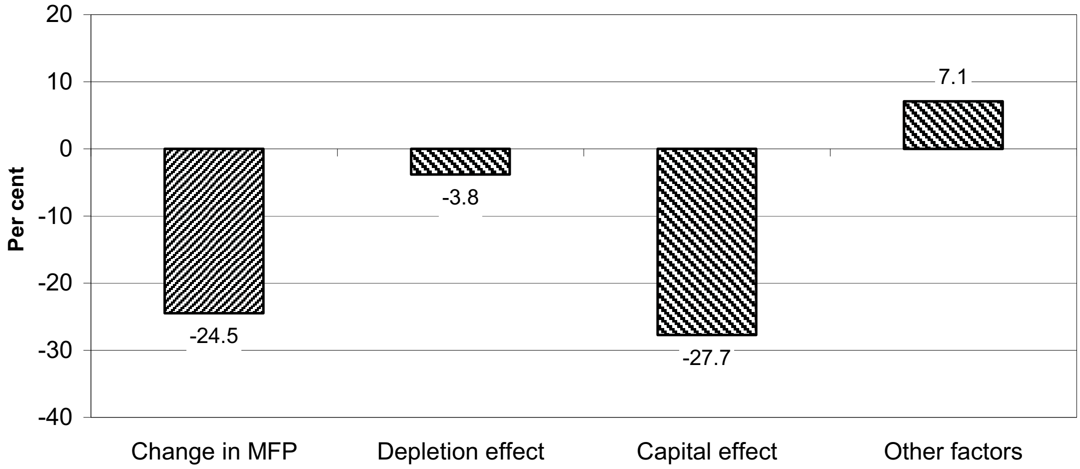
Figure A.4 **Ratio of coal to overburden production, 1991-92 to 2006-07**



Data source: Mudd (2007).

Once the effects of yield changes and the capital investment surge are taken into account, MFP in the coal mining sector is estimated to have grown by around 7 per cent over the period from 2000-01 to 2006-07, rather than to have fallen by nearly 25 per cent (figure A.5). As the majority of the decline in coal mining MFP is caused by the recent surge in capital investment, the decline is likely to be a temporary phenomenon that will be reversed as new productive capacity comes on-stream. Nevertheless, coal mining MFP growth does appear to have slowed so far this decade compared with the previous decade.

Figure A.5 **Coal mining: Contributions to MFP changes, 2000-01 to 2006-07**



Data source: Authors' estimates.

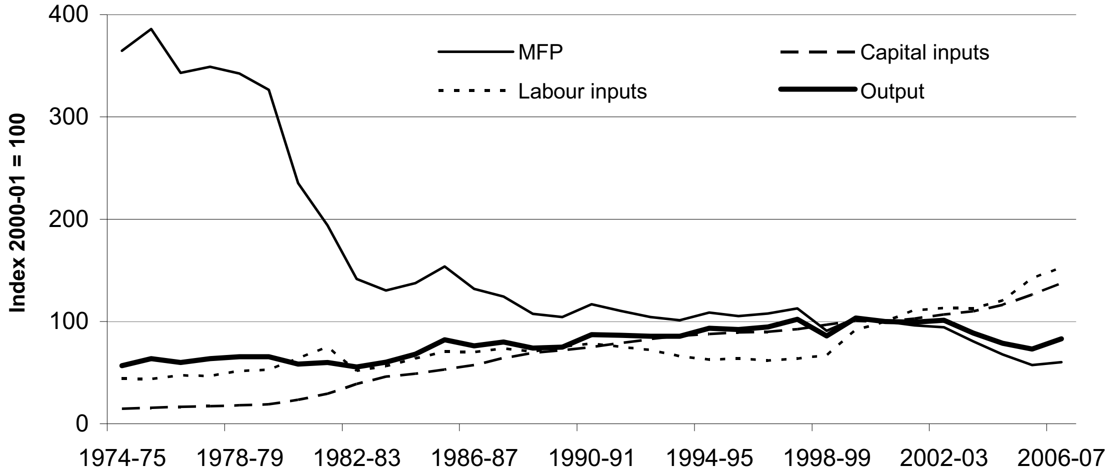
A.3 Oil and gas extraction

Oil and gas production in Australia is a relative newcomer to the mining scene. First commercial production began on Barrow Island in the mid-1950s, but the main petroleum extraction came with the development of the Gippsland basin in the Bass Strait in the late 1960s. Since then, major production of hydrocarbons has occurred in the Gippsland, Carnarvon and Bonaparte basins.

The oil and gas industry is currently one of the largest sub-sectors in the mining industry, contributing 31.2 per cent of mining value added in 2006-07. As such, developments in the sector have a significant impact on the sector as a whole.

A key development in the oil and gas sector is the decline in productivity since 2001, which coincides with the peak of Australian crude oil production. The effects of cumulative extraction from existing fields (outlined in chapter 3) combined with a surge in new capital and labour inputs has led to a sharp decline in MFP that has had a large negative effect on MFP in the mining industry as a whole (figure A.6).

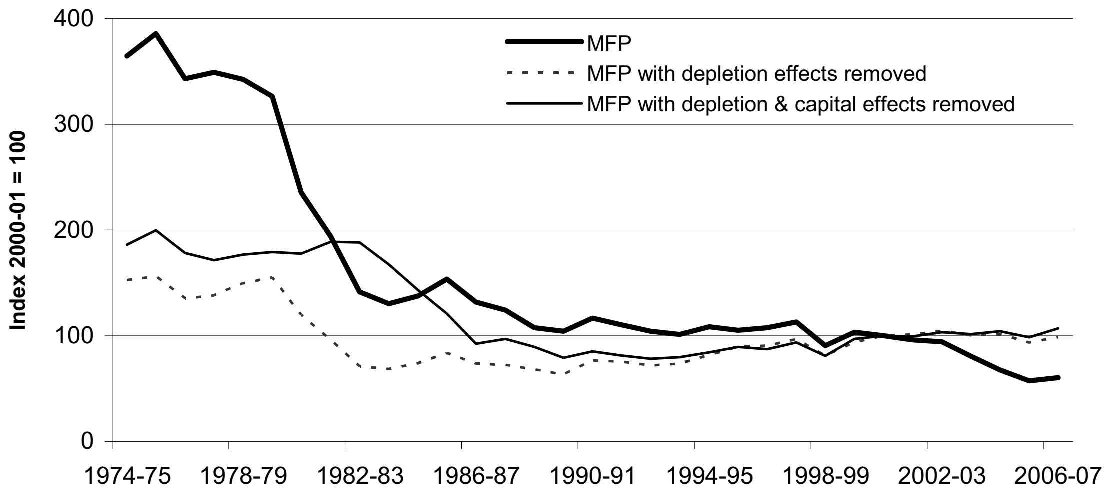
Figure A.6 **Oil and gas extraction: Inputs, output and MFP**



Data source: Authors' estimates.

After removing the influence of lower flow rates (of oil and gas production) due to the maturing of existing fields, a significant proportion of the long-term decline in MFP in oil and gas extraction is explained. Similarly, long lead times in new production capacity are found to be significant factors explaining shorter-term movements in MFP (figure A.7).

Figure A.7 **Oil and gas extraction MFP: Impact of resource depletion and capital effects**



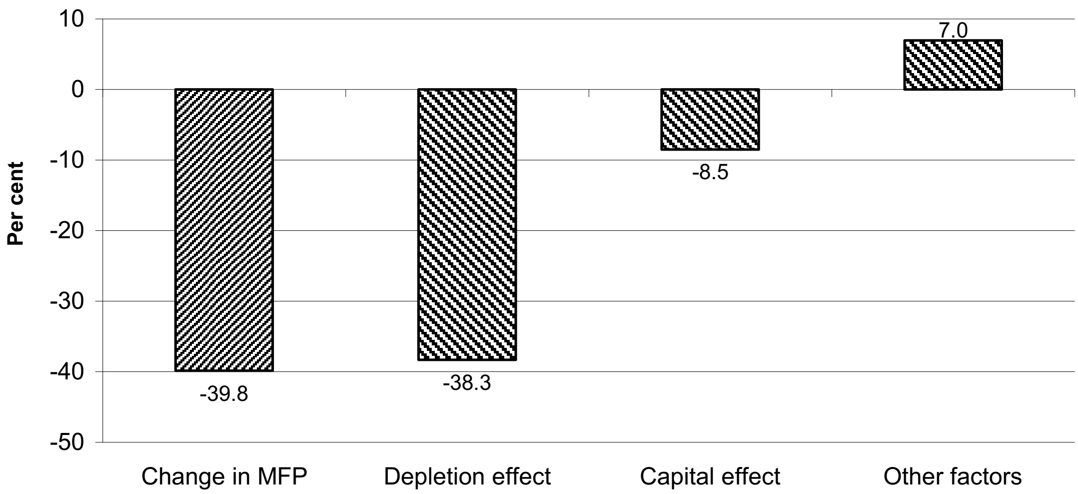
Data source: Authors' estimates.

In contrast to the case of coal mining, the decline in MFP in oil and gas extraction between 2000-01 and 2006-07 is largely explained by yield declines associated with the maturing of existing oil and gas fields (figure A.8). Long lead times in new production capacity are estimated to have contributed negative eight percentage points to the change in MFP over the period, meaning that 'Other factors' contributed a positive amount to MFP growth of around the same magnitude. The negative effects of the recent surge in capital investment in the sector are likely to be temporary, and should be offset over the next few years as new production comes on stream.

While the bulk of the observed depletion is caused by dwindling yields of crude and condensate, there is little in the way of depletion in natural gas. Should demand for gas continue to increase, then depletion effects on productivity should decline as the industry shifts to the (comparatively) more abundant resource.

In terms of recent developments, the sector is continuing its 'geographic shift' away from the Gippsland basin and towards the Carnarvon and Bonaparte basins to exploit new fields with an increased emphasis on the production of natural gas. Improvements in drilling technology have aided this by facilitating access to deeper resource deposits, and through the use of directional drilling to target more complex geological formations. The trend towards the exploitation of deeper deposits, especially for liquid hydrocarbons, is likely to continue.

Figure A.8 **Oil and gas extraction: Contributions to MFP changes, 2000-01 to 2006-07**



Data source: Authors' estimates.

A.4 Iron ore mining

Like the oil and gas sector, the Australian iron ore sector developed comparatively recently, with production growing extremely rapidly from the mid-1960s to the early 1970s. After a comparative lull in production growth in the 1970s and early 1980s, iron ore production began to grow strongly once again, and has continued to grow to the present day. The vast majority of the increase in iron ore production since the late 1960s has been exported, with little change in the quantity used domestically. As a result, iron ore has become a major export industry for Australia, earning just over $16 billion in export revenue in 2006-07 — or 7.5 per cent of the total value of goods and services exports. Over one half of iron ore exports were sold to China in 2006, up from just 18 per cent of total exports in 1999 (ABARE 2007).

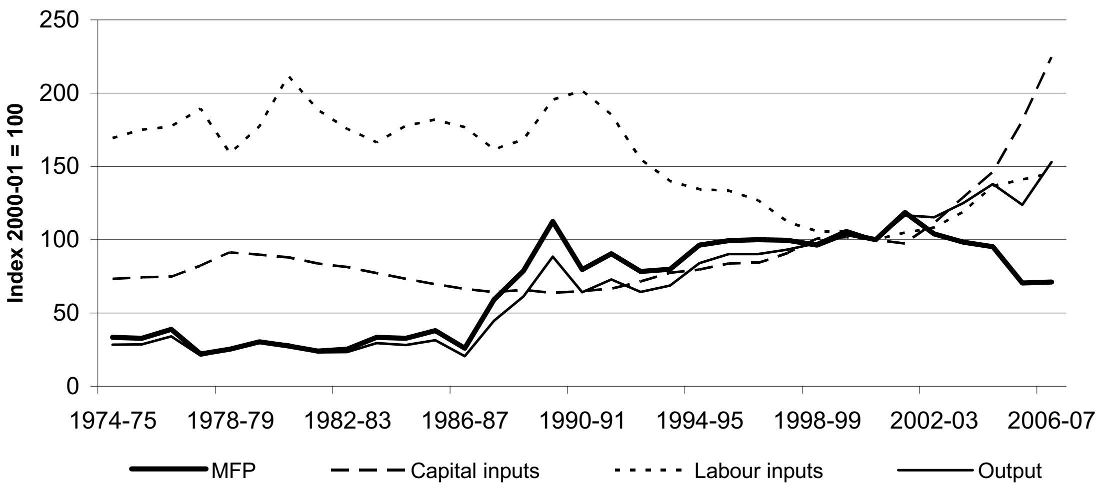
Iron ore production in Australia is currently dominated by two major companies — BHP Billiton and Rio Tinto. Together the two companies accounted for around 92 per cent of production in 2006-07, although recent high prices have encouraged new entrants to the industry. Nearly all iron ore is produced in the Pilbara region of Western Australia.

Iron ore is currently the third largest mining sub-sector in Australia in terms of value added, and is likely to continue to increase its size and importance. According to Mudd (2007, p. 47) Australia holds some of the largest and highest quality deposits of iron ore in the world.

Although there are significant periods of little or no growth in measured productivity in the iron ore sector over the past 32 years, there is nevertheless a strong upward trend (figure A.9). As a result, the average rate of MFP growth over the period is a healthy 3.2 per cent per year, even taking the poor productivity performance over the last six years into account. The period of strong MFP growth between the mid-1980s and the late 1990s is characterised by a substantial increase in the capital to labour ratio in the sector (figure A.9).

Given the substantial reserves of high quality iron ore Australia currently holds relative to production, it would seem unlikely that resource depletion could have played any significant role in explaining trends in MFP growth in the sector since the late 1960s. However, changes in the average grade of iron ore (which, as noted in chapter 3, do not contribute to MFP changes in this sector because the final output is in the form of ore rather than metal derived from ore) are only one possible adverse effect that depletion of reserves over time through cumulative production could be having on measured productivity. For example, Mudd (2007) argues that, as with coal, changes in the amount of waste material that is produced in extracting iron ore could have been occurring over time. Increases in overburden or waste rock production can clearly lead to higher costs of production, putting downward pressure on productivity. In the case of iron ore however, there is little data available to indicate whether or not there has been any significant change in average waste material production in iron ore mining in recent decades.

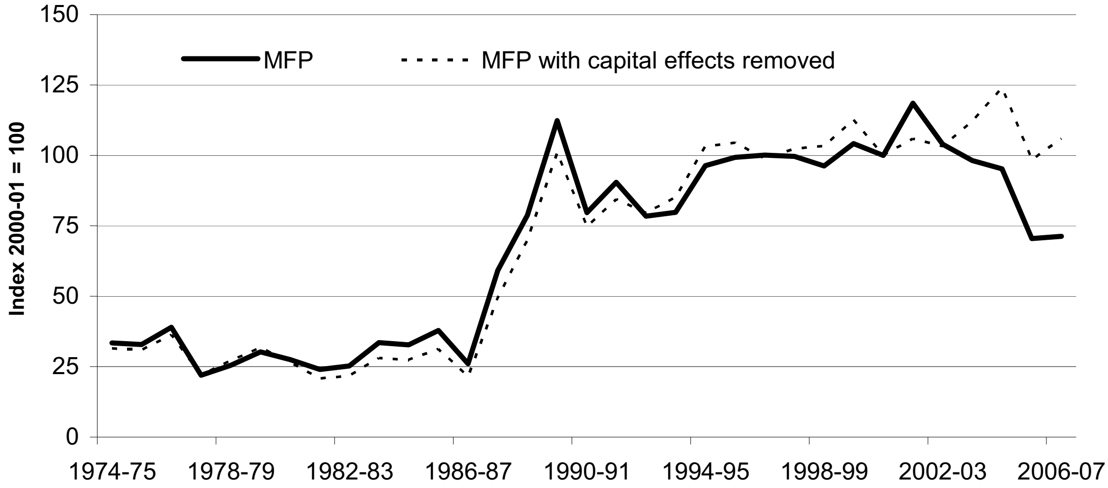
Figure A.9 **Iron ore mining: Inputs, outputs and MFP**



Data source: Authors' estimates.

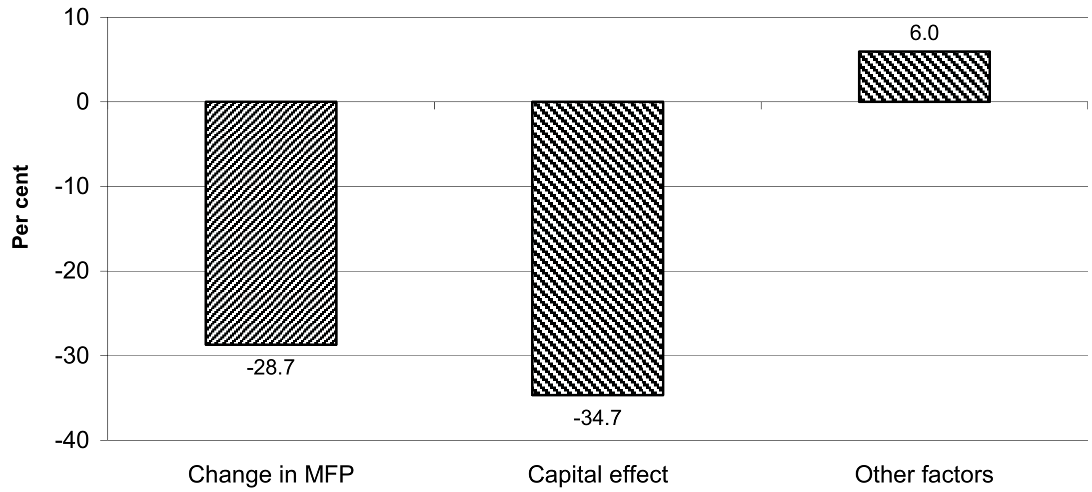
As noted in chapter 3, measured productivity in iron ore mining is not affected by changes in the average grade of ore (although changes in the average iron ore grade have been small), as the output variable is in the form of ore itself (this is in contrast to some of the other metal ore mining industries where the output from mining is measured in the form of metal concentrate or metal per se, rather than 'ore'). However, measured productivity in the iron ore sector is subject to the issue of long lead times associated with investment in new capacity. After accounting for production lags associated with the recent surge in new capital spending in the iron ore sector, measured productivity is found to be significantly higher (figure A.10). In fact, productivity in iron ore mining between 2000-01 and 2006-07 is found to have grown by around 6 per cent, rather than to have fallen by nearly 30 percent. once the effects of the recent capital investment surge in the sector are taken into account (figure A.11). This is despite the fact that iron ore production has also been hampered by very poor weather conditions over the past couple of years, which would almost certainly have contributed adversely to measured productivity.

Figure A.10 **Iron ore mining MFP: Impact of capital effects**



Data source: Authors' estimates.

Figure A.11 **Iron ore mining: Contributions to MFP changes, 2000-01 to 2006-07**



Data source: Authors' estimates.

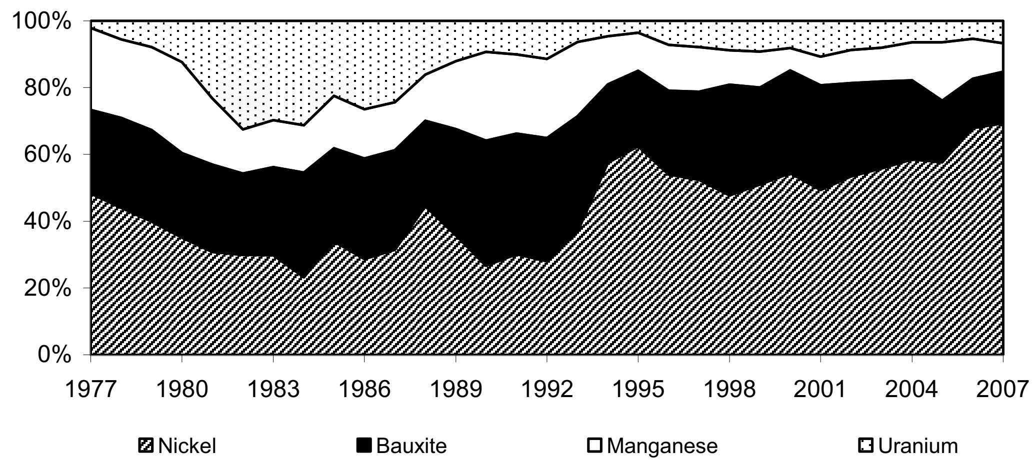
A.5 Other metal ore mining

The ABS classifies several mining operations to the 'Other minerals not elsewhere classified' category. This category encompasses a multitude of non-ferrous minerals, including bauxite, manganese, tin, nickel, tungsten, uranium and lithium.

In Australia's case, the main other metal ores are bauxite and nickel, with manganese and uranium to a lesser extent. These minerals do not have any common purpose, and as such, have price and quantity dynamics that differ. In terms of value added, the 'Other metal ores' category accounted for around 7.2 per cent of the mining sector in 2006-07.

The most notable trend within the category is the increasing importance of nickel over the past 20 years (figure A.12). While nickel production has been increasing over the more recent period (from 169 kilotonnes in 2000 to 185 kilotonnes in 2007), its share of the gross value of production within this category rose substantially due to growth in the price of nickel (up from $14 000 per tonne in 2000 to around $46 000 per tonne in 2007).

Figure A.12 **Gross value of production shares within 'Other metal ore' mining**

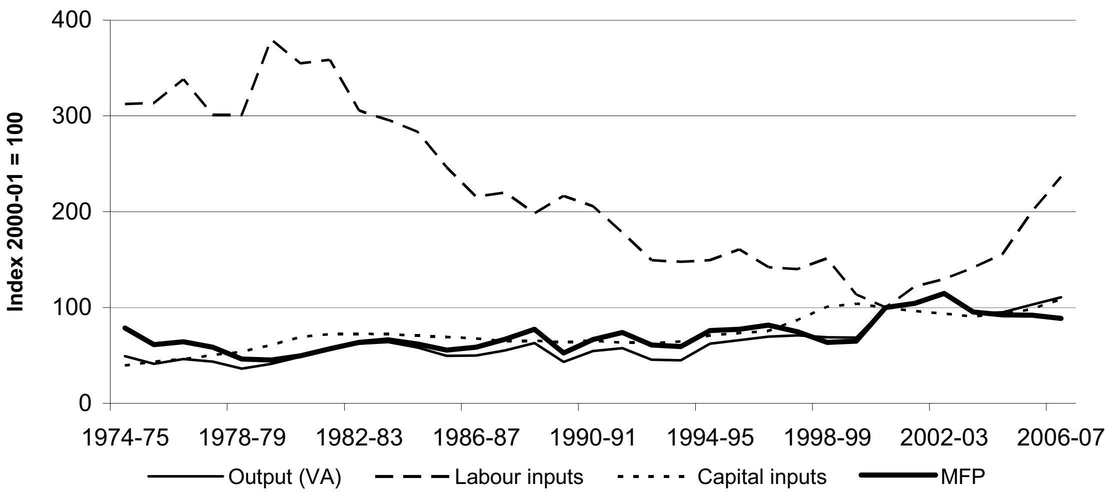


Data source: Authors' estimates using data from ABARE (*Australian Commodity Statistics* 2007).

Productivity trends

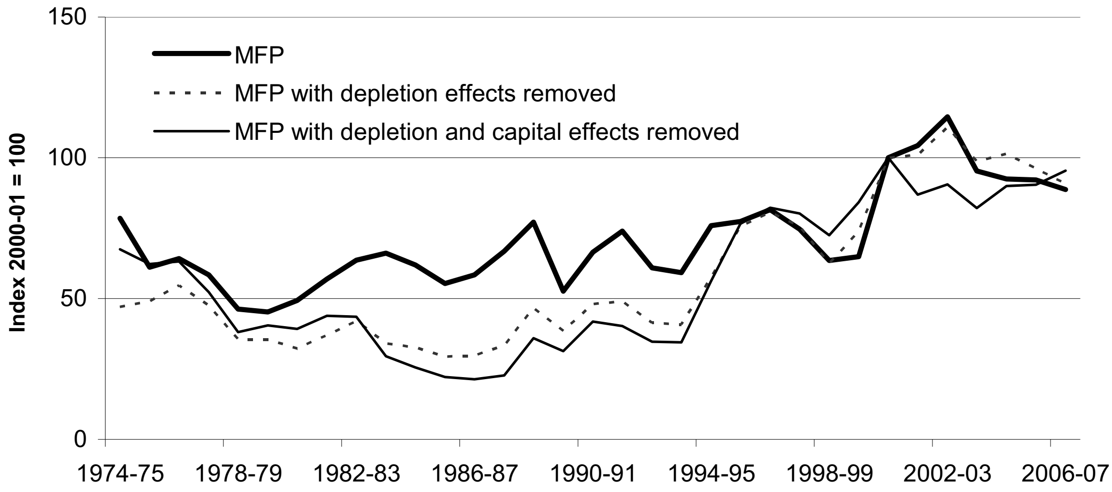
Over the longer term, productivity growth in the 'other metal ores' sector has been comparatively strong, with a compound annual growth rate of MFP over the period from 1974-75 to 2006-07 of 1.8 per cent (figure A.13). Until recent times the growth in MFP was due to capital deepening (an increase in the amount of capital per unit of labour), but the capital to labour ratio has fallen dramatically since 2000-01, and MFP has fallen a little. Unlike other mining sectors, depletion in the form of lower ore grades has not been a major factor influencing productivity trends over the longer term, and has played little role in explaining MFP trends in the sector since 2000-01 (figures A.14 and A.15). This is partly a reflection of the fact that productivity in the bauxite and manganese sectors is not affected by ore grade changes as 'ore' is generally the final output. Hence, only changes in the average ore grades of nickel, tin and uranium are taken into account when estimating the effect of ore grade changes on MFP. This is not to say that other aspects of resource depletion — deeper or more difficult deposits etc — have not contributed to productivity changes in this sector, but a lack of data precludes the effect of these factors from being measured.

Figure A.13 **Other metal ore mining: Inputs, outputs and MFP**



Data source: Authors' estimates.

Figure A.14 **Other metal ore mining MFP: Impact of resource depletion and capital effects[a]**

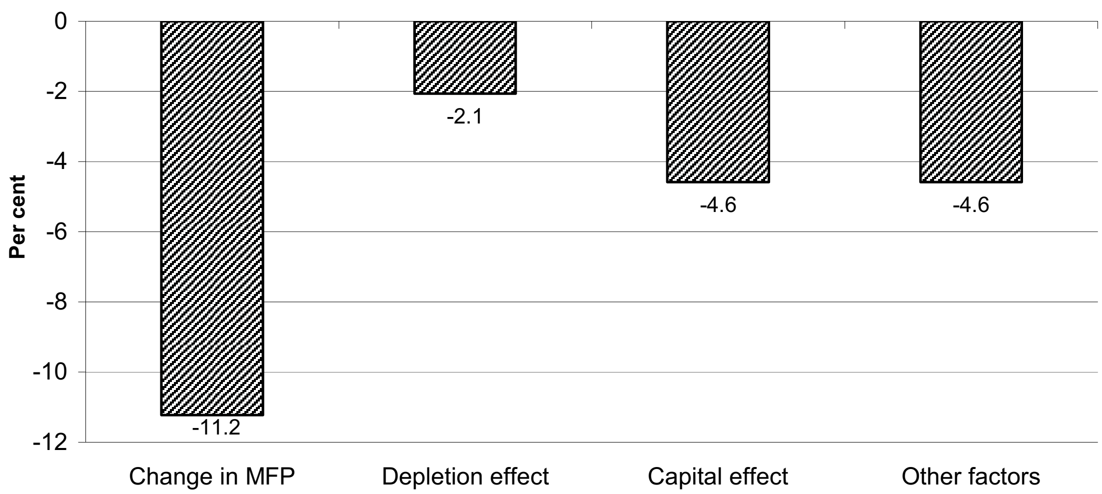


[a] Resource depletion is calculated on the ore grades of manganese, bauxite, nickel and uranium oxide.

Data source: Authors' estimates.

Accounting for the effects of long lead times in response to investment in new capacity changes the year to year movements in productivity in recent years, but does not change the conclusion that there has been a slight decline in MFP in the 'Other metal ores' sector over the period (figure A.15).

Figure A.15 **Other metal ore mining: Contributions to MFP changes, 2000-01 to 2006-07**



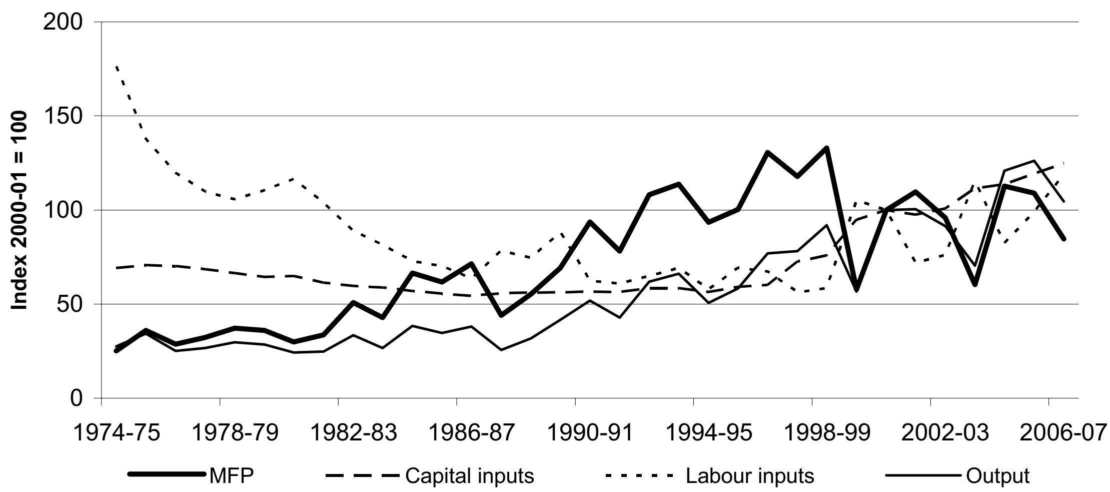
Data source: Authors' estimates.

A.6 Copper ore mining

Copper mining has been performed on an industrial scale in Australia since the 1840s, preceding the original gold mining boom in the mid-nineteenth century by almost a decade. In more recent times, copper has been produced from larger mines as a co-product or by-product with other minerals. The consequences for the accuracy of measured MFP in the copper ore mining sector are unclear. The ABS data on which the MFP estimates for copper ore mining are based suggest that the majority of Australian copper ore production is accounted for by the businesses covered in this classification. As a result, the MFP numbers are likely to be reasonably accurate. On the other hand, the ABS data for 'copper ore mining' exhibit large year to year changes in inputs, output and MFP, and this makes interpreting changes in MFP more difficult. Some of the year to year variability could be the result of individual mining enterprises moving into or out of the survey, or from one industry classification to another as a result of changes in their enterprise mix. As a consequence, the focus in relation to copper ore mining is on general trends in MFP rather than shorter term movements.

With these limitations in mind, it appears to be the case that productivity in copper ore mining grew comparatively strongly from the early 1970s to the late 1990s. Since 1998-99 however, MFP has fallen, on average, and become much more variable from year to year (figure A.16).

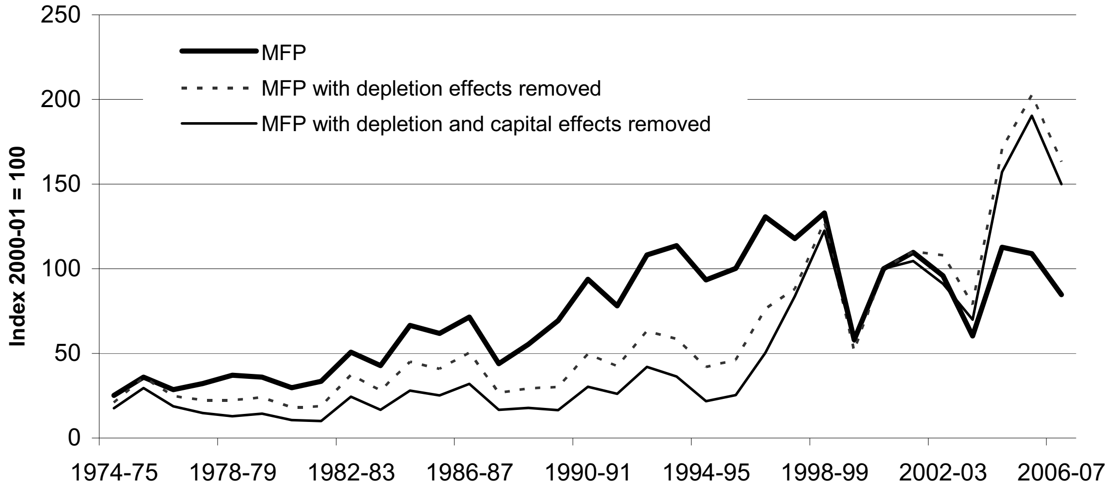
Figure A.16 **Copper ore mining: Inputs, outputs and MFP**



Data source: Authors' estimates.

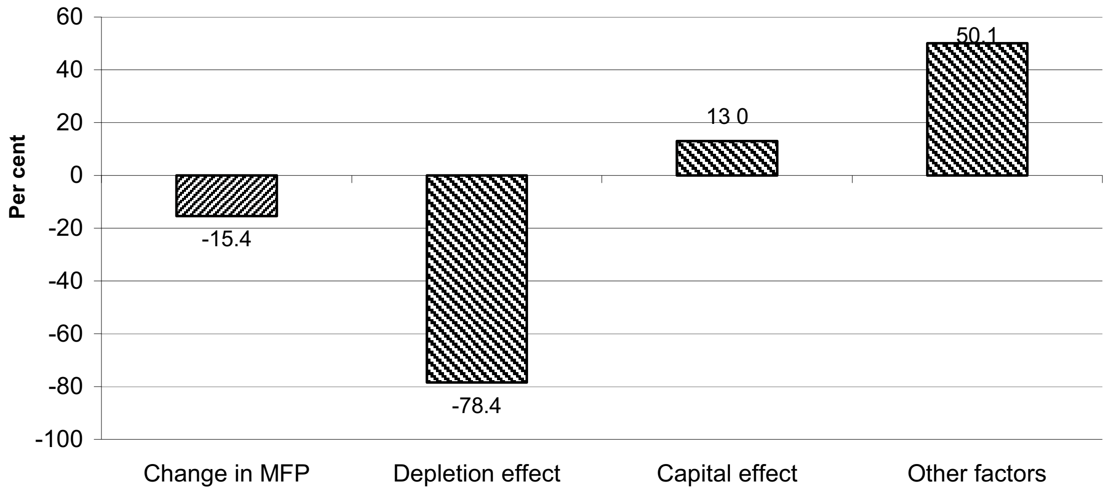
It is estimated that improvements in average ore grades made a significant contribution to the strong increase in copper ore mining MFP during the 1980s and 1990s (figure A.17). From the mid-1990s onwards however, the average grade of copper ore began to fall consistently, contributing to a slowdown in measured productivity growth. Between 2000-01 and 2006-07, the decline in the average grade of copper ore was estimated to have added negative 80 percentage points to the change in MFP. In contrast to many of the other mining industries, new investment in the copper ore mining sector has been comparatively weak in recent years, despite higher output prices. In fact, a slowdown in the rate of growth in new investment in recent years is estimated to have temporarily added around 13 percentage points to MFP growth in the sector. After accounting for the effects of resource depletion and the temporary effects of the capital investment slowdown, 'other factors' are estimated to have made a substantial positive contribution (around 50 percentage points) to the change in MFP in copper ore mining during the period (figure A.17 and A.18).

Figure A.17 **Copper ore mining: Impact of resource depletion and capital effects**



Data source: Authors' estimates.

Figure A.18 **Copper ore mining: Contributions to MFP changes — 2000-01 to 2006-07**



Data source: Authors' estimates.

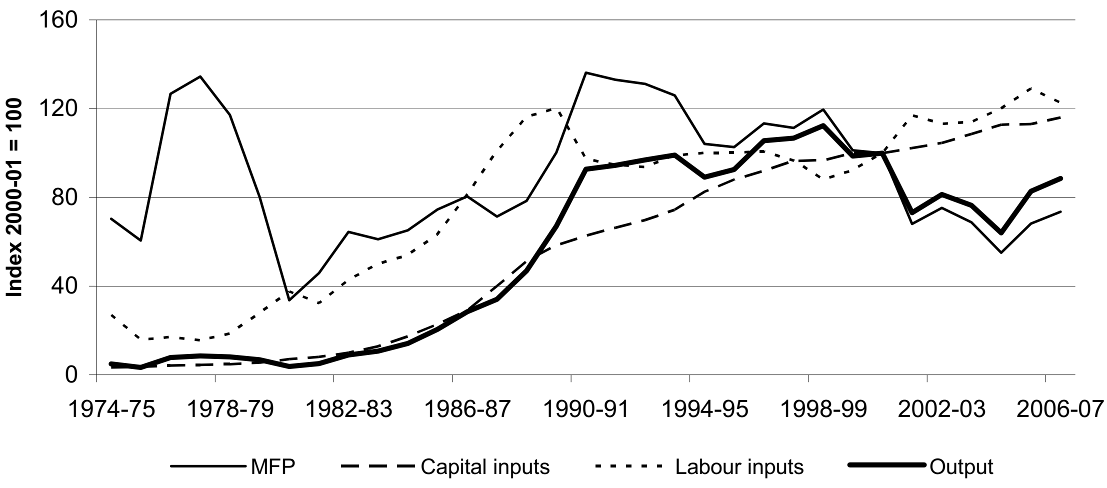
A.7 Gold ore mining

Gold came to prominence in Australia during the first gold boom in the 1850s, making the sector one of the oldest in the mining industry (Close 2004). Easily extractable alluvial gold lured thousands of people from around the world to Australia where the goldfields in Victoria and New South Wales boomed. A second gold boom followed in the 1890s, when large deposits of gold bearing ore were found in Western Australia. Following this second gold boom, production declined and remained low through until the 1970s (with the exception of a small 'mini-boom' during the second world war). The reason behind this slump in production was primarily depletion: the remaining available gold was of such low concentration that extraction was at best uneconomical and at worst impossible. New technology allowed a significant increase in production, but further depletion is now presenting the greatest problem to both production and productivity in the gold mining sector.

In terms of its contribution to the mining sector, gold ore mining is now one of the smaller industries, accounting for just 3.7 per cent of mining value added in 2006-07.

As seen in figure A.19, gold mining productivity in the 1970s was characterised by significant swings. The low production, low input characteristics of gold mining during this period make the MFP series highly sensitive to small changes in output, thus the high volatility of the MFP series should be considered with caution.

Figure A.19 **Gold ore mining: Inputs, outputs and MFP**

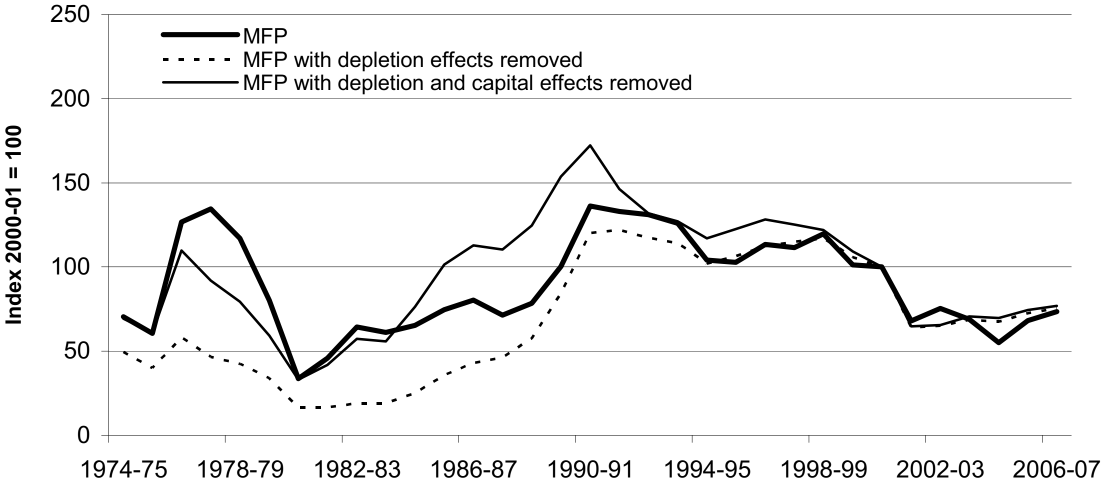


Data source: Authors' estimates.

Gold production and gold productivity increased substantially during the 1980s with the adoption of the carbon in pulp technology, which allowed production from lower concentration ore bodies, and with the discovery of new, large deposits. After peaking in 1990-91 however, MFP in gold ore mining began to trend downward as production growth first slowed and then reversed. The average grade of gold ore has been largely unchanged since 1990-91 however, meaning that the decline in MFP must have been caused by other factors.

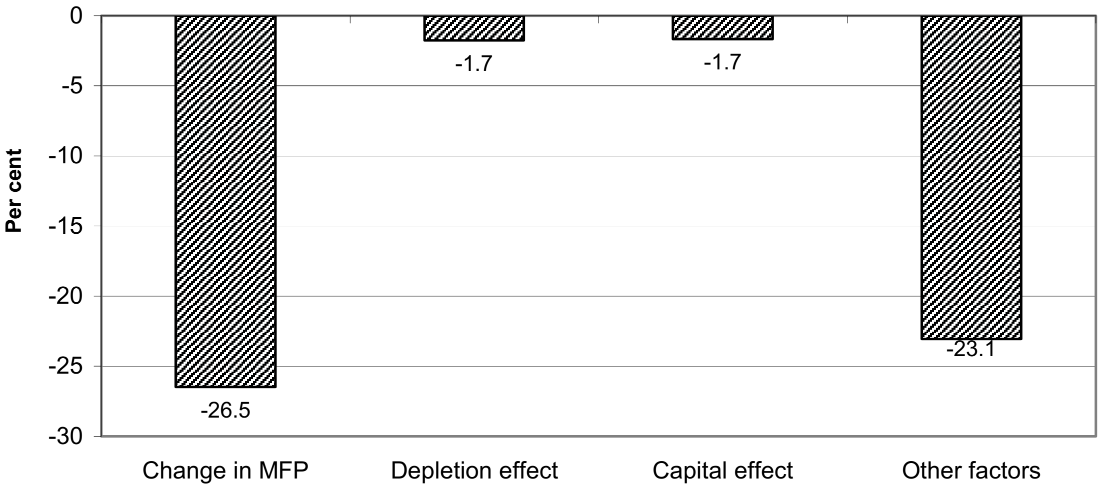
Unlike many other mining industries, recent changes in MFP in gold ore mining are *not* due to the (temporary) effects of investment in new capacity leading output changes (figures A.20 and A.21).

Figure A.20 **Gold ore mining MFP: Impact of resource depletion and capital effects**



Data source: Authors' estimates.

Figure A.21 **Gold ore mining: Contributions to MFP changes, 2000-01 to 2006-07**



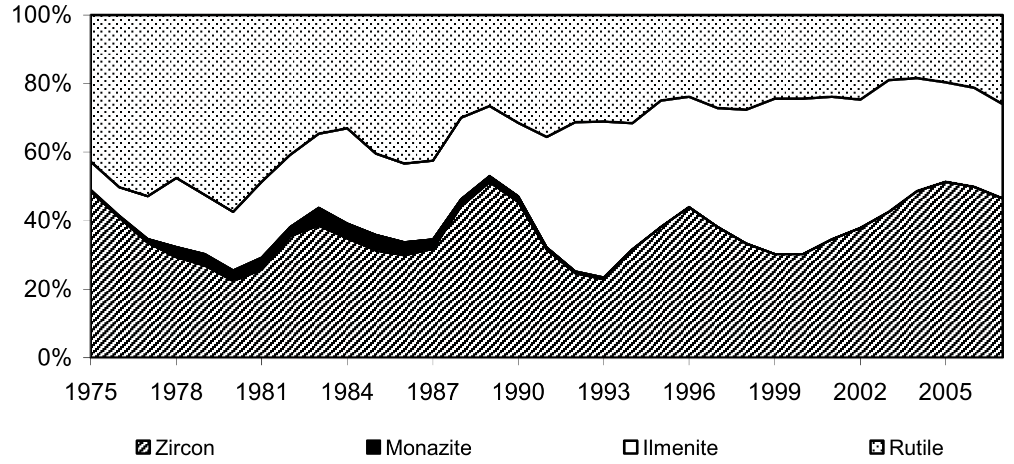
Data source: Authors' estimates.

A.8 Mineral sands mining

Heavy mineral sands — mainly ilmenite, rutile and zircon — have been mined in Australia since the 1930s. Ilmenite and rutile contain titanium dioxide, which is used to make pigment for paint and concentrates. Ilmenite is also converted into synthetic rutile. Zircon has a wide range of diverse uses. Mineral sands are mined in

New South Wales, Queensland, Victoria and West Australia. The gross value of production of mineral sands commodities is distributed roughly evenly between the three main commodities (figure A.22)

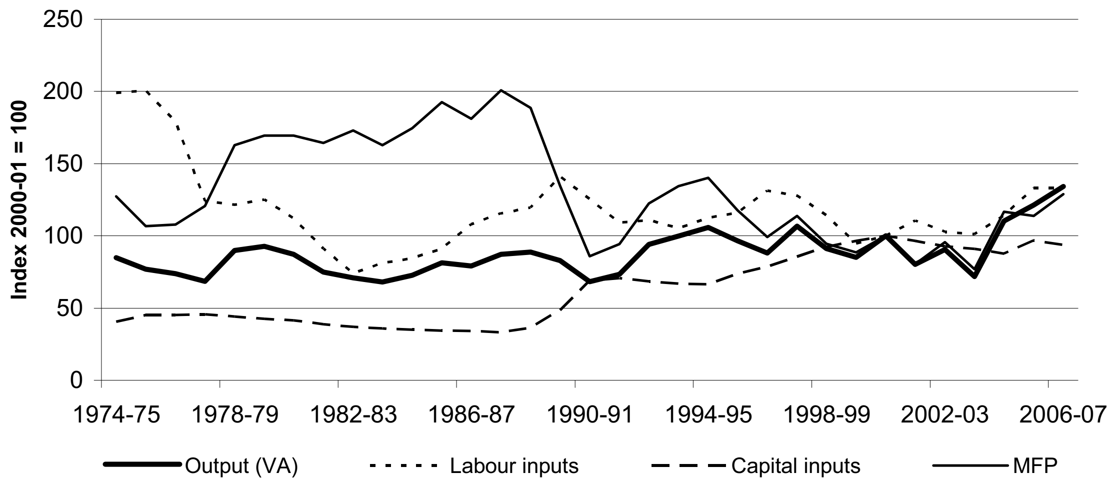
Figure A.22 **Gross value of production shares within mineral sands mining, 1974-75 to 2006-07**



Data sources: Authors' estimates using data from ABARE (*Australian Commodity Statistics* 2007); ABARE (*Australian Mineral Statistics* June 2008).

The mineral sands sector is one of the smaller mining industries, accounting for less than 1 per cent of mining value added in 2006-07 (figure A.23).

Figure A.23 **Mineral sand mining: Inputs, outputs and MFP**

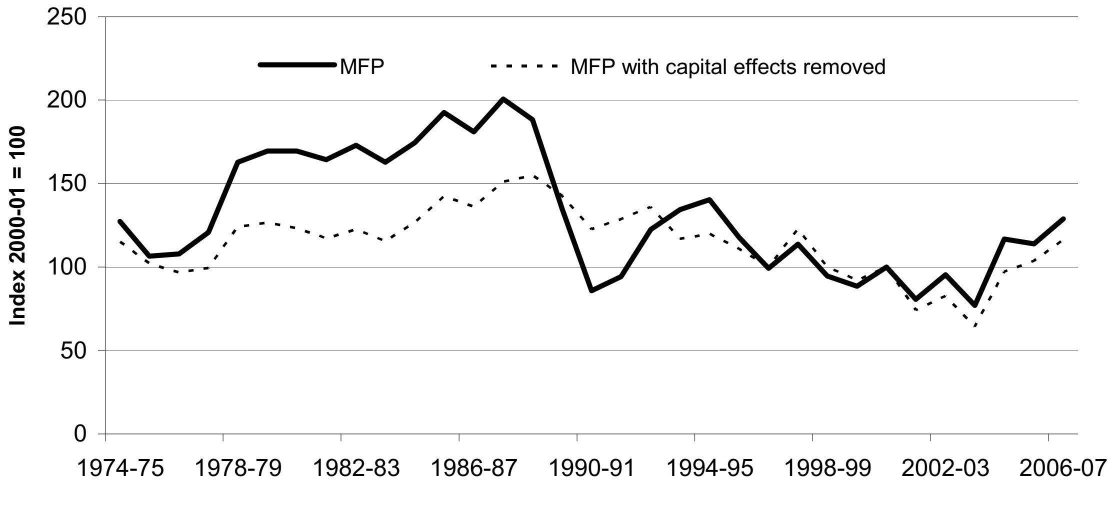


Data source: Authors' estimates.

As a comparatively small mining industry, caveats regarding the accuracy of MFP estimates based on disaggregated ABS mining statistics are particularly relevant for the mineral sands industry — hence the focus is on broad trends over time, rather than year on year changes.

A notable feature of measured MFP in the mineral sands sector is the sharp decline in measured productivity in the late 1980s/early 1990s, which was the result of capital deepening and a decline in output. However, a major contributor to the decline in MFP was the effect of a surge in new investment in the sector from 1988-89 to 1990-91 (figure A.24). After removing the effects of investment cycles, MFP in the sector is much less variable over time, and the sharp decline and recovery in MFP is no longer apparent. The sector is nevertheless characterised by a long period of declining MFP however, which runs from the late 1980s to 2003-04, at which point MFP rebounds on the back of strong growth in production.

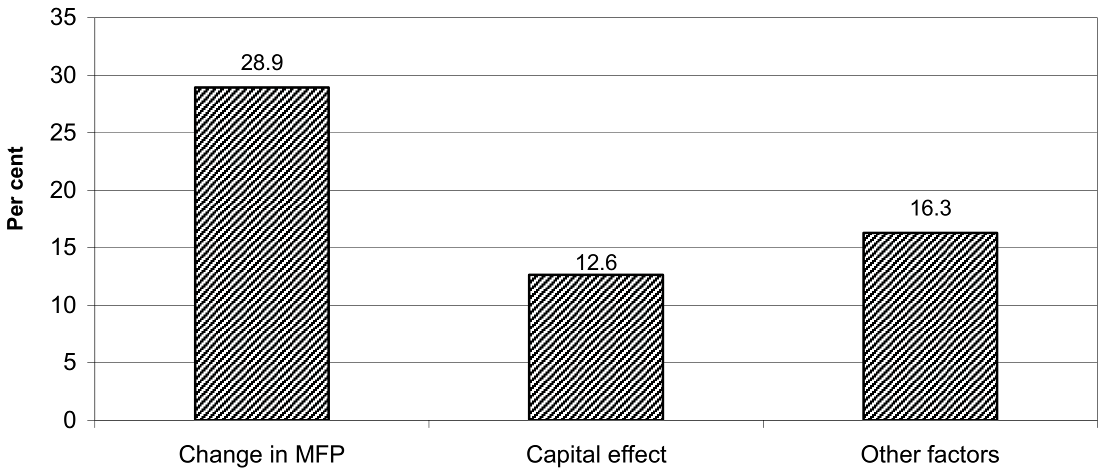
Figure A.24 **Mineral sands mining: Impact of resource depletion and capital effects**



Data source: Authors' estimates.

Apart from a major increase in new investment in the sector in 2005-06, the period from 2000-01 to 2006-7 was characterised by fairly sluggish investment in new capacity. This is consistent with the fact that prices for mineral sands commodities have fallen (in real terms) since 2001-02, rather than risen. As was the case for copper ore mining, a slowdown in new investment made a positive contribution to the change in MFP between 2000-01 and 2006-07 (figure A.25).

Figure A.25 **Mineral sands mining: Contributions to MFP changes, 2000-01 to 2006-07**



Data source: Authors' estimates.

Data on the extent of resource depletion in mineral sands mining is patchy and generally unavailable, particularly in relation to changes in the average grade of ore over time. Hence, no attempt has been made to measure the extent to which ore grade changes may have contributed to changes in MFP in the sector over time.

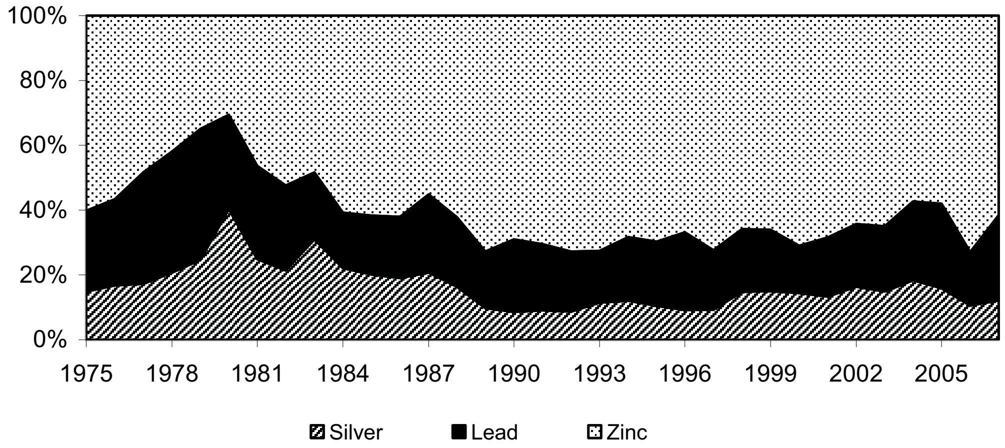
However, anecdotal and other evidence supports the theory that depletion is having a detrimental effect on mineral sands mining productivity. Lee (2001) states that declining ore grades and more complex mineralogy are increasing the cost and effort that must go into mine design. In addition, while exploration has found more reserves of zircon and ilmenite, Australia's reserves of rutile have remained relatively static.

A.9 Silver-lead-zinc ore mining

Silver, lead and zinc are typically mined as co-products from silver-lead-zinc ores, copper-zinc-lead ores, or lead-zinc-copper-silver-gold ores. Lead and silver mining have a long history in Australia, commencing as a major industry with the mining at Broken Hill in 1883. The other well known silver-lead-zinc project is Mount Isa in northern Queensland. Silver is used primarily in jewellery and film, lead for a variety of purposes, and zinc mainly for anti-rust coatings.

In the early years of silver-lead-zinc mining, zinc was considered a useless by-product, and was generally discharged into tailings dumps. Now it is the most important mineral by GVP share, especially in recent years as the price has increased dramatically (figure A.26). Conversely, lead’s significance has diminished through time. This should not be confused, however, with the lead concentrate that is sintered as part of the production process (to crude lead) with a high silver content. Strong growth in zinc and lead prices in recent years has led to an increase in the share of total mining value added that is accounted for by the silver-lead-zinc sector.

Figure A.26 **Gross value of production shares within silver-lead-zinc ore mining**

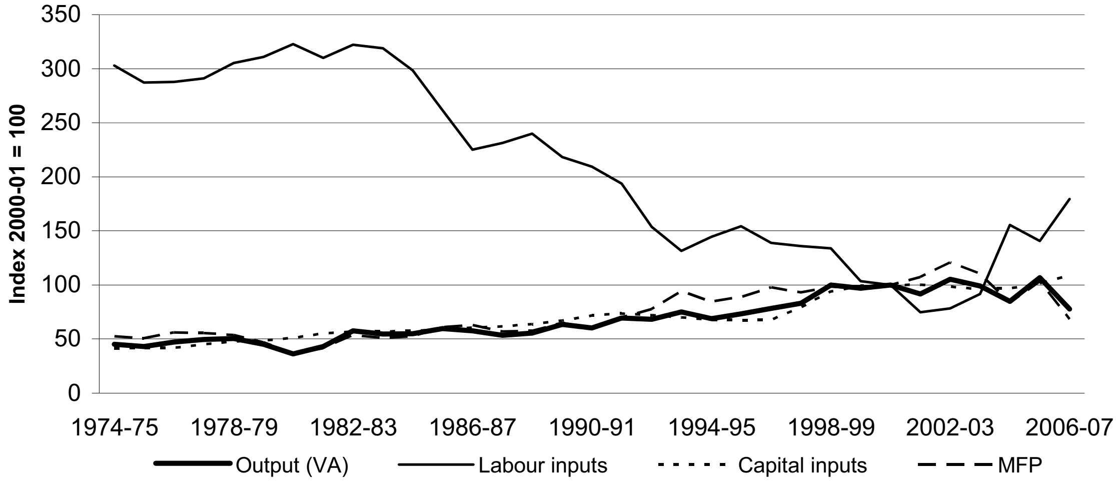


Data source: Authors’ estimates using data from ABARE (*Australian Commodity Statistics* 2007).

As with the ‘other metal ores’ sub-sector, it appears as though trends in MFP in the silver-lead-zinc sector have been affected by changes in the amount of labour inputs (figure A.27). It should also be noted that silver-lead-zinc mining has not suffered as severe productivity declines as other parts of the mining industry. Moreover, over the period for which data are available, MFP growth in the sector has been comparatively strong, averaging 0.8 per cent per year.

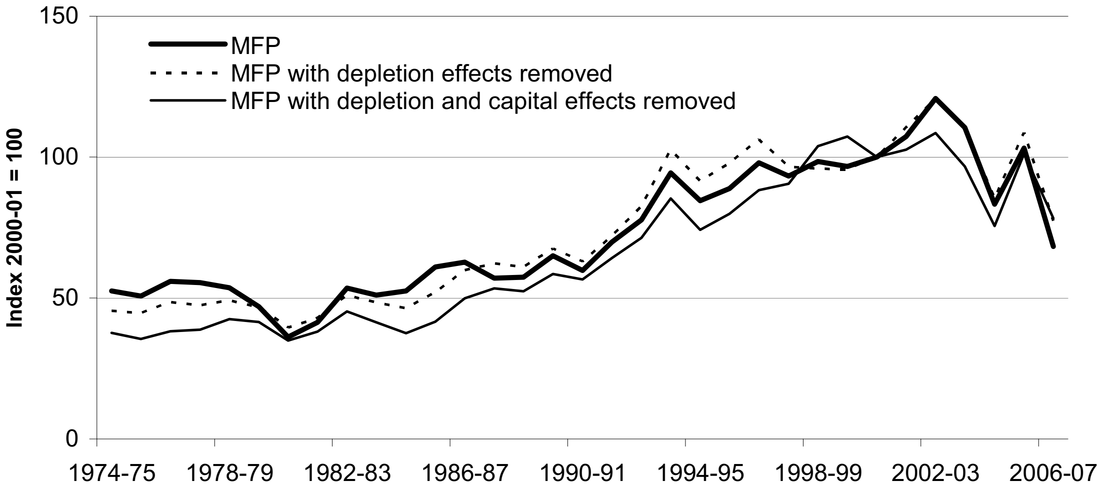
The effects of depletion and lagged capital investment have not, however, been as significant in the silver-lead-zinc mining sector compared to other mining commodities (figure A.28).

Figure A.27 **Silver-lead-zinc ore mining: Inputs, outputs and MFP**



Data source: Authors' estimates.

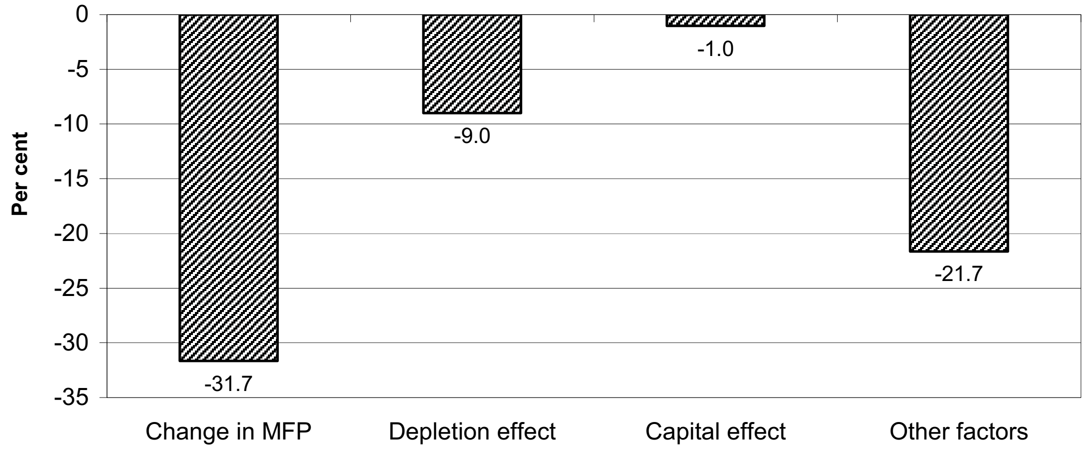
Figure A.28 **Silver-lead-zinc ore mining: Depletion and lagged capital effects**



Data source: Authors' estimates.

One of Australia's older mining industries, silver-lead-zinc mining has seen declining ore grades in recent decades, albeit to different degrees for different metals (see section 3.3 in chapter 3). While zinc has not had a noticeable decline in average ore grade over the past forty years, both silver and lead ore grades have been falling, on average, over the period. Nevertheless, the effect of declining ore grades in silver-lead-zinc mining does not contribute significantly to the longer term trend in MFP in the sector, and does not appear to be a major factor influencing MFP changes after 2000-01. While prices for silver, lead and zinc have, on average, risen significantly in 2005-06 and 2006-07, there has not been a dramatic increase in new investment in the sector. Hence the issue of long lead times in new mining developments does not appear to be a significant factor in explaining recent movements in MFP in the sector either (figure A.29).

Figure A.29 **Silver-lead-zinc ore mining: Contributions to MFP changes, 2000-01 to 2006-07**



Data source: Authors' estimates.